NASA TECH BRIEF

Goddard Space Flight Center

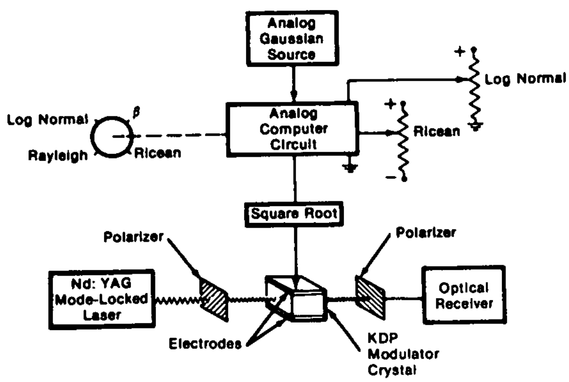
Optical Communication Channel Simulator System

The problem:

Past attempts to simulate the random variations of space-to-Earth and space-to-space optical communication links have involved physically perturbating the air between a source of optical radiation and a detector for the radiation. This has generally been accomplished by heating or introducing air current turbulence. It has been found that such techniques do not yield sufficiently consistent and accurate simulation of random variations to enable laboratory tests of the link to be made in the required manner.

The solution:

The optical transmission link is simulated by positioning a linear optical modulator between an optical carrier source and a receiver for the carrier. The optical modulator is driven by an analog signal, derived from an analog computer circuit, having random variations indicative of the characteristics of the transmission link.



Block Diagram:
Optical Communication Channel Simulator

How it's done:

The optical communication channel simulator is shown in the block diagram. A coherent optical carrier source, such as a Nd:YAG mode-locked laser illuminates an optical receiver, after passing through a linearized optical modulator. The laser source and the receiver simulate the transmitter and the receiver of a space-to-space or space-to-Earth optical transmission link. The linearized optical modulator modulates the carrier from the laser to simulate the perturbations that are a dominant noise source in the transmission of the carrier.

For space-to-space transmission links, the pointing jitter of a laser transmitter is the dominant noise source, and this pointing jitter is simulated by causing the modulator to impose beta statistics on the laser beam. For space-to-Earth transmission, the dominant noise source is atmospheric scintillation, which is simulated by causing the modulator to impose (1) log normal, (2) Rayleigh, or (3) Ricean statistical variations on the laser beam. For the log normal situation, the intensity of the beam itself is modulated. For the Rayleigh or Ricean variations, the atmospheric scintillation is simulated by causing the E-field amplitude, rather than the irradiance, of the optical beam emerging from the modulator, relative to the amplitude of the peak of the spatial Gaussian E-field profile derived from the modulator, to be represented as

$$\frac{A_M}{A_O} = \left(X_1^2 + X_2^2\right)^{1/2}$$

For the Ricean case, X_1 and X_2 are independent Gaussian random variables with different mean values (μ_1 and μ_2) and with variances $\sigma_1^2 = \sigma_2^2$. For the Rayleigh case, $\mu_1 = \mu_2 = 0$. The linearized optical modulator may be either the acousto-optic type or an electro-optic type.

(continued overleaf)

When the modulator is of the electro-optic type, as illustrated in the figure, it includes an electro-optical modulator crystal, having a pair of parallel electrodes positioned on the faces of the crystal parallel to the direction of the laser beam. The electrodes induce an electric field in the crystal at right angles to the direction of propagation of the optical energy through the crystal. Positioned between the laser source and one face of the crystal is a polarizing plate, having its polarization axis inclined at a 45° angle relative to the E-field established in the crystal by the electrodes. Positioned between the crystal and the receiver is a second polarizing plate, having its polarization axis at right angles to that of the first.

To enable the modulator to be driven in accordance with any one of the four random statistical functions noted above (realizing that the equation covers two cases: $\mu = 0$ and $\mu \neq 0$), an analog computer circuit is used which is responsive to an analog Gaussian signal source. The computer circuit can be set to any one of four different configurations: log normal, Rayleigh, Ricean, or beta statistics. The square root of the computer circuit output signal corresponding with the selected statistical distribution is applied, via a square root device, between the electrodes of the crystal to establish random voltage variations across the crystal corresponding with the given statistical functions.

To establish the offset voltages for the log normal and Ricean statistical functions, the computer circuit has a pair of dc input voltages, derived from potentiometers, having settings determined by the Ricean and log normal offsets. One potentiometer is connected between a positive dc source and ground, because the log normal offset is always unipolar. The other potentiometer is connected between positive and negative dc power supply voltages, because the Ricean offset may be positive or negative relative to a zero mean value, which describes the Rayleigh statistical variations.

Note:

Requests for further information may be directed to:

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Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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Categories: 01 (Electronics - Components and Circuitry)
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